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ABSTRACT

The influence cognitive components have on expertise in sport is receiving a great deal of attention. Recent research indicates that levels of expertise in sport can be differentiated with cognitive components. This suggests that skilled athletes do not necessarily have superior physiological and biomechanical systems, but have the same type of task-specific semantic network suggested for experts in areas requiring cognitive involvement. This paper will review four cognitive dimensions (recall of schematic information, perceptual detection, anticipatory cues, and decision making) that have consistently differentiated levels of expertise in sport. (Author)

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Cognition and Expertise in Sport

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Running head: SPORT EXPERTISE

Abstract

The purpose of this article is to illustrate the significance of the cognitive system in sport expertise. A consideration of visual-perceptual abilities, along with cognitive factors and their relationship with sport expertise, will demonstrate the increasing evidence suggesting levels of sport performance can be reliably differentiated on more cognitive dimensions. This article attempts to offer information concerning the nature and cognitive requirements of sport. It is argued that while visual-perceptual factors are inherent in various levels of sport performance, cognitive factors are essential for sport expertise.

Cognition and Expertise in Sport

Hall of Fame baseball player and coach Yogi Berra once said, "90% of sports is mental and the other half is in your head." While humorous, this statement also reflects the significant contribution of psychological factors in sport expertise (Taylor, 1987). While physiological and biomechanical factors are necessary for efficient and successful execution of sport, it is suggested the development of sport-specific cognitive factors are essential for improved sport performance and resultant expertise. For example, in considering high-level sport performers, marked improvements with practice that are characteristic of the early stages of skill acquisition no longer exists. Intense practice may only bring small improvements, leading the athlete to feel a performance ceiling has been set by physiological and biomechanical factors. Further improvements in performance may have to come from psychological factors.

Over the past few years, there has been an increase in the emphasis upon cognitive factors in sport. Historically, sport sciences have emphasized physiological and biomechanical factors when differentiating levels of sport performance. The skilled athlete was believed to possess a number of superior traits or abilities, along with a superior nervous system (Starkes, 1987; Starkes & Deakin, 1984). For example, visual-perceptual abilities such as stereoacuity,

and dynamic visual acuity, and processing skills such as reaction time (Starkes, 1987; Starkes & Deakin, 1984) were hypothesized to differentiate high levels of athletic performance. While the relationship between these factors, which reflect the central nervous system, and sport skill may be logically and intuitively appealing, little empirical evidence is available to provide a direct link (Cockerill, 1981; Sanderson, 1981; Starkes, 1987; Starkes & Deakin, 1984).

Allard and Burnett (1985) have recently suggested that skilled athletes develop the same advanced forms of declarative and procedural knowledge as experts in other tasks. Their research suggests that skilled athletes do not necessarily possess superior nervous systems, but have the same type of task-specific semantic network suggested for experts in other areas requiring cognitive involvement (i.e., chess, and solving physics problems). In a review of the sport perception literature, Starkes and Deakin (1984) examined the relationship between sport skill and "hardware" components, such as stereoacuity and reaction time, and "software" or cognitive components. They suggested that sport performance may be differentiated on more "software" or cognitive dimensions.

The purpose of the present article is to further illustrate the importance of the cognitive system in sport expertise. We will build on the work of Starkes and Deakin (1984) by presenting some of the recent work in cognitive sport psychology, along with studies that have attempted to

assess the relative importance of visual-perceptual factors in sport. We will argue that while visual-perceptual factors are inherent in various levels of sport performance, cognitive factors are essential for sport expertise.

Visual-Perceptual Factors

Stereopsis

Gregory (1973, p. 59) defines stereopsis as the "ability to synthesize two somewhat different images into a single perception of solid objects lying in three dimensional space," or simply the ability to perceive depth and distance binocularly. While the relationship between stereopsis and sport skill is logically appealling, extensive investigations have led to equivocal results (Starkes & Deakin, 1984). Several studies have reported a positive relationship between the ability to perceive depth and sport performance (Bannister & Blackburn, 1931; Graybiel, Jokl, & Trapp, 1955; Olsen, 1956; Ridini, 1968; Winograd, 1942), others have reported a non-significant relationship (Beals, Mayyasi, Templeton, & Johnson, 1971; Olsen, 1956; Shick, 1971).

Banister and Blackburn (1931) suggested that their finding of a positive relationship between depth perception and sport performance in rugby players, was largely due to their sample of rugby players having a greater interpupillary distance, when compared to nonplayers. They concluded that the increased interpupillary distance resulted in enhanced depth perception or stereopsis. In a related study, Clark

and Warren (1935) examined the effects of depth perception and interpupillary distance on performance in basketball, football, and tennis. Their results indicated no significant differences between athletes and nonathletes, leading Clark and Warren to conclude depth perception and interpupillary distance may not be important factors in the sports investigated.

Shick (1971), using a basketball free-throw shooting task, found no significant differences between shooting ability, depth perception, and eye dominance in college women. However, Olsen (1956), using three subject performance levels, found varsity athletes to have superior depth perception abilities in comparison to intramural athletes and nonathletes.

Cockerill and Callington (1981), in attempting to explain the discrepant findings between sport performance and depth perception, suggest more emphasis should be placed on the nature of the particular sport under investigation, and the depth perception measures used. Failure to consider these issues has resulted in inconclusive and unreliable data (Starkes & Deakin, 1984).

Visual Acuity

Visual acuity refers to one's ability to make fine visual discriminations among objects in the visual field (Barlow & Mollon, 1985). It seems obvious that good visual acuity would enhance sport performance. However, Bauscher (1968), Garner (1977), and Martin (1970) in examining the relation of visual acuity to sport performance, found a large

percentage of athletes maintain a high level of performance with inadequate visual acuity. Additional studies (Bannister & Blackburn, 1931; Tussing, 1940; Winograd, 1942) come to the same conclusion, suggesting visual acuity to be independent of athletic ability.

Dynamic visual acuity (DVA) refers to the ability to visually track a moving object, while detecting detail and making fine visual discriminations among the objects in the visual field (Barlow & Mollon, 1985; Burg, 1966; Miller, 1958; Morris, 1977). The ability to visually track an object (i.e., baseball, football, tennis ball, hockey puck) would seem essential for the execution of most sports. In addition, DVA measures would seem to logically and intuitively prove to differentiate levels of sport performance.

Several studies have suggested that DVA is associated with sport performance. The findings of Beals, Mayyasi, Templeton, and Johnston (1971) in basketball, Sanderson and Whiting (1974) in ball catching, and Morris and Kreighbaum (1977) in volleyball and basketball, indicates that DVA may have a significant effect on athletic ability.

In a recent study, however, Starkes (1987) found no conclusive evidence for a relationship between DVA and level of sport performance. Three groups of subjects, consisting of women field hockey players, varying in ability (expert, moderate ability, novice), were tested at three DVA speeds (100, 125, and 150 degree change per second). The procedure and equipment used are fully elaborated by Sanderson and

Whiting (1974; 1978). The results indicated no significant differences across ability groups for the three DVA speeds assessed. Starkes (1987) notes that a ceiling effect may have occurred during this task as subjects performed with minimal errors at the fastest speed, suggesting subjects possessed the necessary ability at the speeds employed. While the expert group demonstrated no significant DVA advantage, the results are inconclusive.

Ocular Movement

In examining the visual movements involved in batting a baseball, Hubbard and Seng (1954) concluded that batters, when tracking the ball, used pursuit movements of the eyes with the head remaining fixed. In addition, Hubbard and Seng found that eye movements stopped when the ball was eight to fifteen feet from the plate, suggesting pursuit movements of the eye breakdown at high velocities.

Falkowitz and Mendal (1977) and Trachtman (1973) investigated the relationship between visual skills and batting averages. Both studies found a significant correlation between eye movement efficiency and batting averages.

Research examining the relationship between eye movements and sport performance has come to the general conclusion that the more experienced the athlete, the more efficient the eye movements (Gregg, 1987). This line of research suggests that eye movement efficiency may be taught or developed with practice.

Perceptual Organization

Perceptual organization is the ability to make sense of the complex perceptual stimuli in our visual field, resulting in more efficient perception. Figure-ground perception, which is the tendency to differentiate the target of perception from the surrounding stimuli, is a primary factor in perceptual organization. The ability to organize stimuli into figures and ground increases our perceptual skills, leading one to assume perceptual organization to be an important factor in sport performance.

However, Williams and Thirer (1975) found no relationship between figure-ground perception and fencing skill. In a related study, Pargman, Bender, and Deshaies (1975) came to a similar conclusion with basketball shooting skills.

Deshaies and Pargman (1976), in studying the visual abilities of college football players, concluded that visual perception ability is not related to the level of athletic performance.

In briefly reviewing some of the research on visual-perceptual factors and their relation to sport, it is apparent that evidence for a direct link between these factors and sport performance is equivocal. Cockerill and MacGillivary (1981) and Gregg (1987) provide excellant sources for references to studies of visual-perceptual factors and sport.

Cognitive Factors

Memory for Game Situations

The organization of stimulus information and its subsequent retrieval has been shown to reliably differentiate levels of expertise in cognitive skills. Specifically, the recall paradigm has demonstrated the ability of experts to take in a large quantity of task-specific information in a brief period of time and subsequently recall the information in meaningful units. Chase and Simon's (1973a, 1973b) study of recall of chess positions by chess players demonstrated that experts are able to encode more information in a limited time when compared to non-experts, and subsequently recall the information in meaningful units. Experts exhibited superior recall for structured chess positions only, with recall being similar across levels of expertise when presented with unstructured chess positions. This suggests the superior recall of the expert is a function of experience with the subject matter and not attributable to superior memory capacity.

The recall paradigm, in recent years, has been used to examine the recall of structured versus unstructured game situations in sport. Allard, Graham, and Paarsalu (1980) used a four-second recall paradigm to successfully demonstrate that varsity basketball players recall game structured information more accurately than intramural basketball players. Recall of unstructured information was similar for both groups. Similar results were found by

Starkes (1987; Starkes & Deakin, 1984) using an eight-second recall paradigm. Starkes found that experts, consisting of the Canadian National Women's Field Hockey team, were superior to varsity players and physical education students in recall of structured field hockey situations.

Allard, Graham, and Paarsalu (1980), used a recognition task to examine the level of encoding of structured and unstructured basketball game situations. Their results indicated that basketball players were significantly more accurate than nonplayers at the recognition task. Based on these findings, Allard, Graham, and Paarsalu suggest basketball players encode structured information more deeply than nonplayers. Their results were consistent with earlier studies in chess (Chase & Simon, 1973a, 1973b) and bridge (Charness, 1979).

Chunking in Recall of Schematic Sport Information

While the previous studies show evidence of expert's sensitivity to pattern or structure of their sport, the characteristics or nature of the perceptual structures, or chunks, that are stored and subsequently retrieved are unclear. Chase and Simon's (1973a, 1973b) explanation for chess experts' superior recall is their ability to chunk the information into meaningful units. To facilitate the testing of their hypothesis, Chase and Simon developed an experimental technique, based on temporal boundaries, to isolate and define chunks in recall. The technique involved using subjects' successive glances at a chess board as an index of chunking, while trying to reconstruct a chess

position on a separate chess board, while the two boards remained in plain view. It was assumed that the subject would encode only one chunk per glance while reconstructing the position. This technique confirmed the five-second recall findings that increased expertise led to increased chunking size and frequency.

Utilizing an experimental procedure adapted from Chase and Simon (1973a, 1973b), Allard and Burnett (1985) recently reported data suggesting superior chunking behavior by experts in sport. Their experts consisted of members of the Canadian National Women's Basketball team, while control subjects were psychology graduate students. Allard and Burnett presented their subjects with 10 schematic diagrams of basketball plays, which they were allowed to study for five seconds, after which time they were to reproduce as much of the figure as they could recall using a colored marker. This procedure continued with a different color marker until the play was reproduced to the subject's satisfaction. Recall was scored by counting the number of elements of the play recalled. Elements were defined as the starting position of each player, the route of each player, any action the player was to perform, and the path of the ball. As expected, expe.. players took significantly fewer looks than did the control subjects to complete the play. Their results suggests basketball knowledge may be organized in a similar semantic network proposed for experts in skill domains that require obvious cognitive involvement (Allard & Burnett, 1985).

In explaining chunking behavior in recall of task-specific stimulus information, Chase and Simon (1973a, 1973b; Simon & Chase, 1973; Simon & Gilmartin, 1973) have proposed a "perceptual chunking hypothesis." Perceptual chunking involves perception by coding the position of entire chunks or several pieces, by storing chunk labels in short-term memory and subsequently decoding at the time of recall. Two critical features of the perceptual chunking hypothesis are that chunks are independently perceived and that recall requires decoding chunk labels in short-term memory (Egan & Schwartz, 1979).

Egan and Schwartz (1979), however, have pointed out several problems with these critical features. First, chunk independence does not allow for global display processing. For example, Master chess players can perceive the global characteristics (e.g., "some kind of attack formation") of a diagram in addition to individual properties. Second, a group of display pieces may not form a functional unit or chunk, independent of other functional units. The functional units must be context dependent. Third, studies (Charness, 1976; Frey & Adesman, 1976) using a Brown-Peterson paradigm (Brown, 1958; Peterson & Peterson, 1959) have shown that a variety of interpolated tasks have no influence on recall performance of skilled chess players. These studies strongly question Chase and Simon's (1973a; 1973b) position that chess information is stored in short-term memory.

As an alternative to perceptual chunking, Egan and Schwartz (1979) have proposed a "conceptual chunking

hypothesis," which links chunking to the organization of long-term memory. Conceptual chunking consists of a few primary features. First, skilled subjects rapidly identify a concept for an entire display. Second, skilled subjects may systematically retrieve functional units which are related to the conceptual category stored in long-term memory. Third, conceptual knowledge of the display enables skilled subjects to systematically search displays in order to verify details suggested by the conceptual category. Based on these features, conceptual chunking seems to overcome some of the difficulties of perceptual chunking (Egan & Schwartz, 1979).

Recently, Garland (1988) conducted a series of three experiments to examine the nature of the perceptual processes used by sport experts to perceive schematic sport information. A primary objective of the research was to explore the critical features of both the perceptual and conceptual chunking hypotheses within the framework of recall of schematic football diagrams.

In Experiment one, a modified version of the experimental task used by Chase and Simon (1973a, 1973b) and Allard and Burnett (1985) was used to isolate and identify the perceptual structures (chunks) in which relevant sport-specific information is hypothesized to be encoded. Experts, consisting of high school football coaches, and novices, consisting of undergraduates, were presented with slides of schematic football diagrams, each varying in structure and complexity. Subjects were allowed to study each slide for five seconds, after which time they drew their

recall with a colored pencil. If desired, the same slide was presented for another five seconds, after which time recall was drawn with a different color pencil. This procedure continued until each diagram was reproduced to the subjects satisfaction. The basic assumption is that the subject will encode and recall one perceptual structure, or chunk per five second study interval. In addition, a construction task was used to measure subjects' ability to produce elements of a diagram, based on limited features, without prior exposure to the diagram (Egan & Schwartz, 1979).

The results indicated that experts, in comparison to novices, recall larger perceptual structures when presented structured diagrams only, regardless of complexity. In the construction task, experts (M = 9.77) produced significantly more correct elements than did novices (M = 3.91), suggesting limited features were sufficient for experts to generate the correct functional elements and units of the diagrams.

An examination of the first perceptual structures for all subjects revealed the average number of elements recalled was within the traditional short-term memory capacity (7 $\pm$ 2), except for experts in the structured/complex (M = 20.8) and structured/easy (M = 10.2) conditions, where the number of elements recalled exceeds the traditional short-term capacity.

The conceptual chunking proposal (Egan & Schwartz, 1979) is consistent with two primary aspects of the findings. First, experts in comparison to novices, recalled larger perceptual structures after the initial five second

presentation of structured stimuli only. This finding may not represent recall of multiple independent chunks, as suggested by perceptual chunking, rather the recall of a large group of elements may reflect a "generate-and-test process" (Egan & Schwartz, 1979). Increased knowledge of a conceptual category may enable experts to retrieve elements systematically, because functional units may be conceptually related to display categories in long-term memory. By knowing the conceptual category of a display, experts may generate more elements within each functional unit for a strength or recency check (Bower, Clark, Lesgold, & Winzenz, 1969; Egan & Schwartz, 1979). Secondly, the results of the construction task are consistent with conceptual chunking. Experts correctly output more elements than novices, based on limited stimulus features, without prior exposure. This finding implies that the limited features of the answer sheet were sufficient to prompt experts to the conceptual category, resulting in output of relevant functional units (Egan & Schwartz, 1979).

Experiments two and three examined the conceptual chunking proposal that chunking is linked to the organization of long-term memory. Experiment two used a long-term memory recognition task to determine if experts encode stimulus information more deeply than novices. The results indicate that experts, in comparison to novices, were superior at recognizing structured schematic diagrams only, regardless of complexity. The results are consistent with conceptual chunking, suggesting stimulus information extracted from the

schematic diagrams was processed relatively deeply in a brief period of time, stored in long-term memory, and eventually retrieved.

Experiment three, using a sorting task adapted from Allard and Burnett (1985), examined the conceptual chunking proposal that experts should discover more semantic relations among elements and chunks. The results indicate that experts' clusters were more discriminating, suggesting a more refined and discriminatory hierarchical organization structure, based on the dynamics of the game.

In summary, the superior memory skill of experts in a variety of skill domains may not involve rapidly decoding chunk labels from a limited capacity short-term memory, rather memory skill may be more conceptual in nature, linking chunking to the organization of concepts in long-term memory (Egan & Schwartz, 1979).

Decision Accuracy and Efficiency

The ability of an athlete to encode and retrieve sport specific information in an efficient and accurate manner is extremely valuable in reliable and instantaneous decision making. Chase and Ericsson (1981) have argued that a highly organized hierarchical system of encoding and retrieving information is necessary for reliable and fast retrieval. Intuitively, experts should encode and retrieve highly complex and game structured information faster than nonexperts, resulting in faster decision making.

Allard and Burnett (1985) have demonstrated that expert basketball players have a more discriminating and deeper

hierarchical processing structure when compared to nonplayers. Thirty schematic diagrams of various aspects of basketball were presented to 11 members of the Canadian National Women's Basketball Team and 10 nonplayer control subjects. The subjects were instructed to sort the pictures, using as many categories as they chose. The results indicated that experts used significantly more categories (M = 7.18) than did nonplayers (M = 4.2). A hierarchical cluster analysis indicated that the experts' clusters were more discriminating, resulting in six distinct groupings as opposed to two distinct, less discriminating groupings for the nonplayers. Experts sorted the pictures according to significance of skill and used a deeper processing structure, indicating a more refined and discriminating hierarchical retrieval structure. Garland (1988) got similar findings in football.

Chase and Ericsson (1981) reported that with practice and training, the encoding and retrieval processes become faster and more reliable, due to the strengthening of the relationship between the encoding structure, retrieval structure, and relevant retrieval cues. This position is illustrated in a study by Thiffault (1974), which examined decision making training in ice hockey players. Thiffault presented an untrained group, consisting of ice hockey players, with slides depicting tactical game situations. Players were instructed to verbally respond "shoot," "pass," or "skate" as quickly as possible, with regard to the most appropriate move for the player with the puck. The training

group, also consisting of ice hockey players, was presented similar slides during 10 training sessions, and was instructed to respond in the manner previously mentioned. The results indicated that trained players made significantly faster tactical decisions than did the untrained players, supporting Chase and Ericsson's (1981) suggestion that decision making time may increase with training and practice.

Recently, Starkes (1987) reported further evidence of differentiating levels of performance on complex decision making abilities. Starkes visually exposed (1/60 seconds) three groups of field hockey players (expert, moderate ability, novice) to 24 slides of schematic field hockey situations. Subjects were to quickly and accurately decide the optimal offensive move for the player with the ball, by responding "shoot," "dribble," or "dodge." The results indicated that expert players do not necessarily make faster tactical decisions, but rather, make significantly more accurate decisions in comparison to the lower level performers. These results are in opposition to the findings of Allard and Starkes (1980) in volleyball, and Thiffault (1974) in ice hockey, who reported faster, not necessarily more accurate decisions.

Other Cognitive Abilities

Starkes and Deakin (1984) in a review of the sport perception research on "Hardware" (stereoacuity and reaction time) and "Software" (cognitive) components affecting sport performance, suggested the perceptual "software" components, such as recall, perceptual anticipation, signal detection,

and decision making provides a better way of examining skilled performance. The perceptual anticipation research findings of Jones and Miles (1978) in tennis, Bard and Fleury (1981) and Salmela and Fiorito (1979) in ice hockey, Bard, Fleury, and Carriere (1975) in gymnastics, and Starkes (1987) and Starkes and Deakin (1984) in field hockey, indicates that skilled performers are able to make use of advanced visual cues to anticipate the location of relevant stimulus information and utilize the information to enhance performance.

Starkes (1987), in examining several perceptual "hardware" and "software" abilities in field hockey players, came to the following conclusions concerning the skilled field hockey player:

1. Dynamic visual acuity does not differ from moderate ability and novice players.

2. Skilled players have only average reaction time.

3. Coincident anticipation ability does not differ from moderate ability and novice players.

4. Skilled players have superior recall of game-structured information.

5. Skilled players make better use of advanced visual cues.

6. Field hockey skill does not require rapid visual search ability.

7. Skilled players make more accurate, not faster tactical decisions.

Conclusion

In considering the various visual-perceptual and cognitive factors and their relationship with sport expertise, it is increasingly evident that levels of sport performance can be reliably differentiated on more cognitive dimensions. The present article has attempted to offer information concerning the nature and cognitive requirements of sport. It is suggested, that within sport, skills which have traditionally emphasized physiological and biomechanical factors, may also require substantial cognitive involvement (Allard & Burnett, 1985).

In explaining cognitive involvement in sport expertise, one needs to consider the role of memory, skill acquisition processes, and experience. The acquisition of memory skills may help explain the superior memory abilities of experts in the recall and recognition of sport information and superior accuracy in complex decision making. Chase and Ericsson's (1981) theory of skilled memory argues that exceptional memory is the consequent of more efficient storage and retrieval processes in long-term memory. They specify three principles in the acquisition of skilled memory. First, meaningful encoding, which is done by rapidly encoding and storing semantic information in long-term memory. Second, retrieval structures are constructed by associating retrieval cues with encoding. Third, extensive practice accelerates the encoding and retrieval operations in long-term memory.

Within every skill domain, few people emerge as experts

possessing the necessary skills which are far superior to the novice. In general, experts are regarded as possessing memory abilities quite different from those of novices. Ericsson (1985) has suggested that any consideration of the nature of exceptional memory requires a theory of normal memory organization. Implications of such a theory would lead to questions of memory systems being genetically endowed versus acquired through practice and experience. Ericsson (1985) has proposed the "memory skill hypothesis" which argues that memory ability is a skill acquired through extensive practice. Extensive practice is suggested as the key factor in memory skill acquisition, accounting for most or all of the variability in memory skill. In the present review, memory systems have been shown to reliably differentiate levels of sport expertise. Such evidence suggests experts in comparison to novices, in various sport domains have acquired superior memory processes and structures through extensive practice, accounting for a large percentage, if not all of the variability in sport expertise.

In considering skill acquisition processes, Fitts (1964) has suggested that skills are developed in stages, starting with a cognitive stage, leading to an associative stage, which results in the final autonomous stage. Anderson (1982) has modified Fitts' stages to describe cognitive skill acquisition. The initial stage is the acquisition of declarative knowledge, followed by a knowledge compilation stage where declarative knowledge is translated to procedures, resulting in the final procedural stage where

procedures are characterized as autonomous.

In addition to Fitts' (1964) and Anderson's (1982) skill acquisition theories, several other theories have been proposed to account for the processes used in skill acquisition (Adams, 1987; Anderson, 1983; Fitts & Posner, 1967; Schneider & Shiffrin, 1977). While a review of these theories and others is beyond the purpose of this article, the primary processes of each theory are qualitatively similar.

The initial acquisition phase is generally characterized by slow, deliberate processing, as strong demands are placed on the cognitive system. During the initial phase, a great deal of attention is given to the formulation of production strategies and the understanding of the task. With extensive practice, cognitive processing demands are reduced, and strategies fully formulated, resulting in increased performance speed and accuracy. In the second phase, production strategies are further refined with use, leading to the final phase, which is characterized by effortless and automatic processing. Extensive and consistent practice throughout the acquisition process and beyond appears to be the key to performance and resultant expertise (Ackerman, 1988).

Novices do not seem to make use of the cognitive processes utilized by sport experts, indicating breakdowns in memory skill acquisition and/or overall skill acquisition. Inefficient, and likewise ineffective cognitive processing abilities and production strategies, may account for a large

percentage of the performance variability in sports.

In sport expertise, an important question still remains; what is the relative contribution to cognitive skill of physically performing the task versus observing and study the task (Starkes, 1987)? Can cognitive sport expertise develop in the absence of physical expertise? This becomes an important question when considering the qualitative differences between the expert sport performer and the expert coach. Both of these sport experts require cognitive skills, however the role of physical ability varies. Presumable differences in the formulation and eventual proceduralization of their production strategies and declarative knowledge bases, suggest that physical ability may not be necessary to support cognitive skill (Starkes, 1987). This issue is unclear and is in need of empirical investigation.

It must be emphasized that the primary factor affecting level of expertise in sport is extensive practice and experience. The organization and eventual refinement of the expert's vast semantic network requires a substantial amount of practice. This is consistent for all skill domains. Thus, as Ericsson (1985) has proposed, experience and extensive practice are the primary variables affecting memory skill acquisition and cognitive skill acquisition in sport.

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